UPDATED STANDARDIZED CATCH RATES IN NUMBER FOR SWORDFISH (*Xiphias gladius* L.) CAUGHT BY THE SPANISH LONGLINE FLEET IN THE MEDITERRANEAN SEA, 1988- 2013.

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SUMMARY

A General Linear Modeling (GLM) approach to analysis of variance was used to analyze swordfish logged catch rates in number of fish from 24,239 trips carried out by the Spanish surface longline fleet addressed to this species in the Western Mediterranean for the period 1988 -2013.

RESUMEN

Mediante técnicas de Modelado Lineal Generalizado (GLM), se analizaron las tasas de captura de pez espada en número de peces, transformadas mediante aplicación de logaritmos naturales, procedentes de 24.239 mareas de la flota española de palangre de superficie dirigido a esta especie en el Mediterráneo Occidental desde 1988 a 2013.

KEYWORDS

Catch/effort, Least squares method, Abundance, Long lining, Swordfish.

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1. MATERIAL AND METHODS

1.1. Basic data.

Data for the analysis were obtained from the Spanish longline activity in the Mediterranean Sea targeting swordfish from 1988 to 2013. As in previous analyses (Mejuto & de la Serna, 1995; Ortiz de Urbina & de la Serna, 1999; Ortiz de Urbina *et al*, 2004, Ortiz de Urbina *et al*, 2007; Ortiz de Urbina *et al*, 2011), information of catch by vessel/trip- including date, area of the catch, catch in number and fishing effort- was recorded by the Information and Sampling Network of the Spanish Institute of Oceanography (IEO) at the most important landing ports for the aforementioned fleet. A comprehensive description of the Spanish longline fishery directed to swordfish in the Mediterranean Sea was previously presented by de la Serna *et al* (2004).

Raw data for positive trips (trips with at least one fish) were estructured as follows: vessel code, date of landing, landing in number of fish, number of sampled fish, catch by LJFL (5 cm interval), quadrant, area (5 x 5 degrees), number of sets, hooks by set and type of bait. A total of 24, 239 records were available for the analyses.

Following traditional criteria, nominal effort by trip was defined as number of hooks (in thousands of hooks) computed from the number of sets carried out during the trip and the mean number of hooks by set.

1.2. Model and Specifications.

Three previosly defined areas (Mejuto & de la Serna, 1994) were used in the analyses. As regards temporal definition, it corresponded to the following quarters:

Quarter 1: January, February, March
Quarter 2: April, May, June
Quarter 3: July, August, September
Quarter 4: October, November, December

The basic multiplicative model (Gavaris, 1980; 1988) was defined as follows:

$$Ln\ (CPUE) = \varepsilon + Y_i + Q_j + A_k + Q_j{*}A_k + e_{ijk}$$

ε = overall mean
Y_i = effect year i
Q_j = effect quarter j
A_k = effect area k
e_{ijk} = normal error

2. RESULTS AND DISCUSSION.

Table 1 shows the number of observations per year/area/quarter in the analyses. A total of 24,239 positive trips were used in the analyses. In general, the number of observations by cell may be considered satisfactory.

The deviance analysis results for catch rates standardization are shown in **Table 2.** Final model for catch rates in number of fish included factors *Quarter* and *Area* as well as the corresponding interaction *Quarter*Area* (all factors statistically significant at the 1% level, except the *Quarter*Area* interaction for model with catch rates in number of fish). The variability rate explained by the model was about 14 %.

Diagnostic plots (residuals vs. fitted values and cumulative normalized residual plots) for CPUE in number, shown in **Figure 1**, seem to be not far from expected. Annual relative abundance indices with corresponding 95% upper and lower confidence limits (**Table 3** and **Figure 2**) were obtained from the marginal means adjusted for the GLM statistically significant terms.

3. LITERATURE CITED

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Table 1. Number of observations by year/quarter/area for the Spanish longline fishery in the Western Mediterranean.

	Quarter 1			*Quarter 2*			*Quarter 3*			*Quarter 4*		
year	*Area 2*	*Area 3*	*Area 5*	*Area 2*	*Area 3*	*Area 5*	*Area 2*	*Area 3*	*Area 5*	*Area 2*	*Area 3*	*Area 5*
1988	1	33	4	43	60	28	80	69	177	49	49	18
1989	37	38	5	140	77	2	223	100	162	114	43	27
1990	47	27	0	117	54	12	224	150	285	115	71	69
1991	35	44	2	108	75	0	162	101	146	115	74	0
1992	21	55	0	80	54	10	358	187	95	130	147	17
1993	163	51	5	218	38	19	541	85	74	254	85	18
1994	196	56	0	195	54	7	596	169	136	327	129	32
1995	124	60	39	234	39	2	563	202	93	340	180	108
1996	158	73	13	149	27	0	382	208	100	197	140	46
1997	81	48	4	110	12	0	427	65	72	219	18	55
1998	96	8	21	122	40	0	281	84	71	170	59	44
1999	59	32	13	54	4	23	177	70	35	97	78	54
2000	53	6	25	37	16	0	97	148	44	80	68	27
2001	88	16	0	104	17	0	199	217	0	191	105	0
2002	160	10	2	112	11	0	280	299	2	205	89	2
2003	80	13	0	89	56	0	93	233	0	94	131	0
2004	35	23	0	12	11	0	87	161	4	65	94	44
2005	16	21	0	10	0	0	41	93	8	27	71	18
2006	9	2	0	8	0	0	58	46	4	40	56	17
2007	14	7	7	9	4	4	13	31	38	14	18	59
2008	0	17	10	5	8	25	96	65	69	29	61	19
2009	2	25	17	13	23	50	298	155	117	46	11	20
2010	35	20	43	20	7	27	286	89	155	17	20	34
2011	32	26	36	31	9	33	376	103	106	28	7	46
2012	25	33	44	1	36	17	158	91	54	27	6	1
2013	68	125	71	29	121	58	611	266	134	89	53	62

Table 2. Deviance analysis of explanatory factors in the lognormal model for swordfish catch rates in number of fish from the Spanish longline fishery in the Western Mediterranean.

Model factors (lnCPUEn)	*df*	*residual deviance*	*change in deviance*	*% of total deviance*	*model % deviance*	*p-value*
NULL	24238	14323				
Year	24213	13422	900.83	6.29	6.29	2.20E-16
Year Quarter	24210	12471	950.90	6.64	12.93	2.20E-16
Year Quarter Area	24208	12455	16.71	0.12	13.05	8.27E-08
*Year Quarter Area Quarter*Area*	24202	12388	66.56	0.46	13.51	2.20E-16

Table 3. GLM least squares means by year, standard error, coefficient of variation, relative abundance indices by year and corresponding upper and lower 95% confidence limits based on a normal approximation. Catch rates in number of fish. Spanish longline fishery in the Western Mediterranean.

	lsmean lnCPUEn	*std. Error*	*CV(%)*	*CPUEn*	*upper 95%*	*lower 95%*
1988	2.282	0.035	1.518	9.800	10.489	9.157
1989	1.849	0.029	1.578	6.353	6.727	6.000
1990	2.072	0.028	1.333	7.943	8.385	7.525
1991	1.749	0.030	1.731	5.746	6.097	5.415
1992	1.824	0.028	1.527	6.196	6.543	5.866
1993	1.835	0.025	1.343	6.264	6.574	5.969
1994	1.935	0.023	1.208	6.922	7.247	6.612
1995	1.916	0.024	1.236	6.792	7.114	6.484
1996	1.659	0.025	1.498	5.253	5.515	5.003
1997	1.628	0.028	1.693	5.096	5.379	4.828
1998	1.800	0.028	1.566	6.052	6.396	5.727
1999	1.605	0.032	1.996	4.979	5.302	4.676
2000	1.619	0.034	2.087	5.046	5.392	4.723
2001	1.605	0.029	1.798	4.977	5.266	4.703
2002	2.171	0.026	1.216	8.768	9.234	8.326
2003	1.647	0.031	1.859	5.190	5.510	4.887
2004	1.413	0.036	2.519	4.108	4.404	3.831
2005	1.613	0.045	2.773	5.020	5.480	4.599
2006	1.765	0.050	2.811	5.842	6.439	5.301
2007	2.037	0.052	2.548	7.668	8.489	6.926
2008	2.078	0.040	1.939	7.986	8.642	7.379
2009	1.464	0.032	2.174	4.324	4.602	4.062
2010	1.591	0.032	1.995	4.909	5.224	4.613
2011	1.711	0.031	1.796	5.535	5.878	5.211
2012	1.897	0.037	1.948	6.669	7.170	6.203
2013	1.641	0.025	1.528	5.162	5.422	4.914

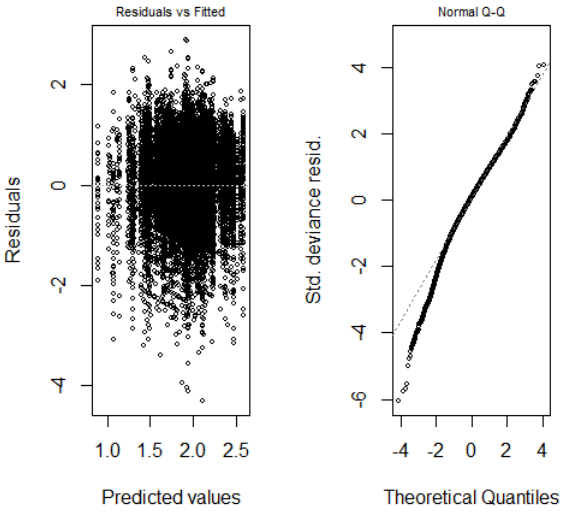

Figure 1. *Diagnostic plots*: residuals vs. fitted values (left) and cumulative normalized residual plot (right) for the lognormal model fit to swordfish catch rates (number of fish).

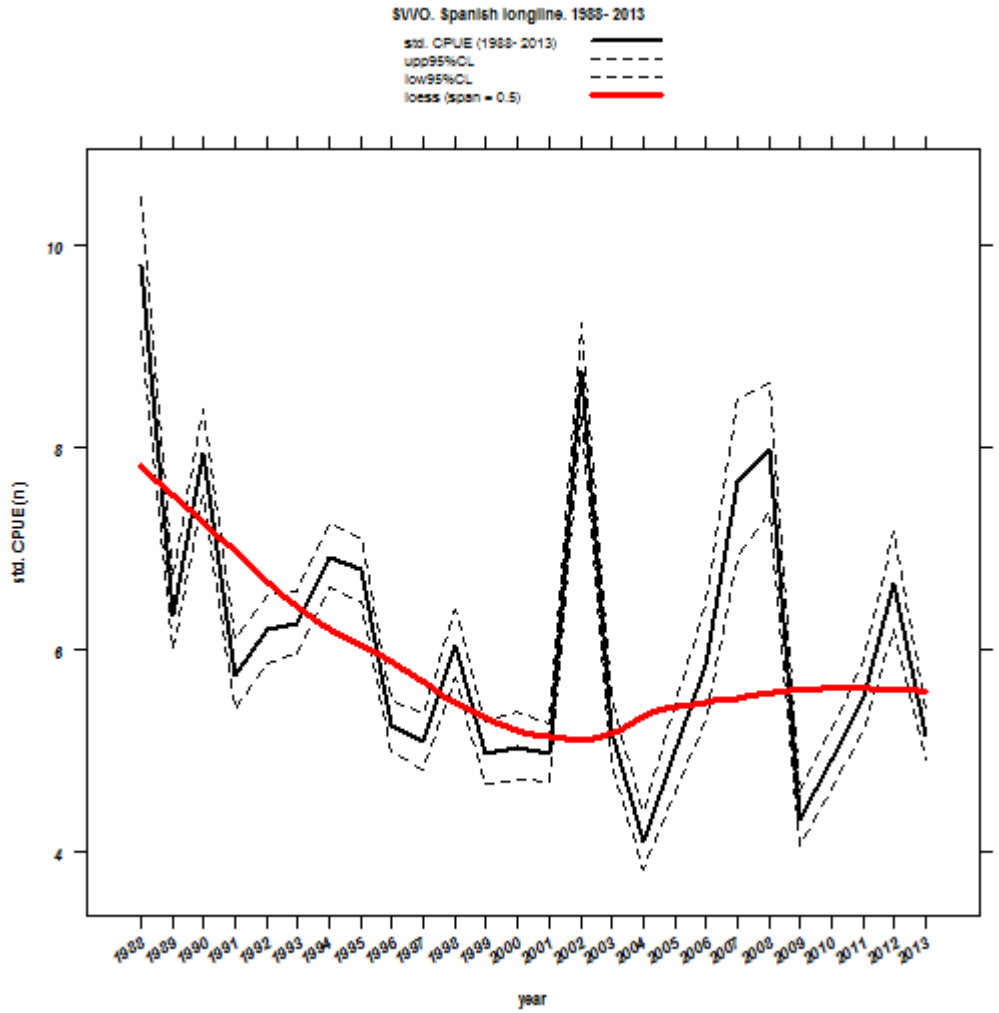

Figure 2. Standardized CPUE index, corresponding 95% confidence limits (normal approximation) and trend (LOESS fit). Number of fish. Spanish longline fishery in the Western Mediterranean.